SLAG—IRON AND STEEL

By Hendrik G. van Oss

In a blast furnace, crude or pig iron is made by stripping the oxygen and other impurities from iron ore by means of high-temperature reactions with reducing agents (mainly carbon) and fluxes. The impurities and fluxing agents combine to form a liquid silicate melt called iron or blast furnace slag, which floats above the liquid crude iron and which is tapped (removed) from the blast furnace separately from the iron. The crude iron is then transferred to a steel furnace, where the iron's residual carbon content of about 4% is reduced, typically to less than 0.5%, and other impurities are removed. This process involves lime and silicate fluxes and the formation of steel slag. Steel furnaces, particularly electric arc furnaces (EAF), also may use scrap iron and steel feed, but again the impurities are removed by fluxing agents that form a slag. Apart from the original furnace feedstock impurities, slags (especially steel slags) also may contain significant amounts of entrained free metal. The physical attributes of solidified slags—glassy, metallic, or stony; hard and compact or vesicular—depend mainly on how the material was cooled. The cooling method also largely determines the uses for the slag. After cooling, the slag may be further processed (mainly crushing) prior to being sold. Sales of iron and steel slags in 2003 totaled about 19.7 million metric tons (Mt), worth almost $300 million, and included a mix of material derived from current slag production, old slag piles, and imports.

Slags have been used for construction purposes, especially for road surfaces, since Roman times, but with the advent of the industrial revolution, iron and steel production rose dramatically and the volume of slag produced soon far outpaced consumption of slag. The result was growth of unattractive slag piles. By the mid-19th century, new uses for slags had been found, particularly as aggregate in hydraulic cement concrete and, for some slags, as a cementitious material in its own right. Consumption remained modest, however, until the 20th century, when slag was found to be an excellent aggregate for asphaltic concrete (asphalt) road paving. This and other new uses, together with a rapidly increased use of hydraulic cement concrete worldwide, led to the consumption of most existing slag piles and current slag consumption roughly keeps pace with new slag production. Ferrous slags are now properly recognized as useful coproducts of the iron and steel industry rather than waste products.

Notwithstanding their utility, most slags have very low unit values compared to those of pig iron and steel products. Most iron and steel companies, accordingly, consider the slag they produce to be a nuisance and contract with outside slag-processing companies to get rid of it; the slag-processing company may also be responsible for cooling the slag. Although the financial arrangements vary, typically the processing company receives the cooled slag for free, crushes it to various marketable sizes, uses screens and magnetic separators to recover entrained metal from the slag (this metal to be returned to the furnace for a low charge), sells the slag on the open market, and pays a small percentage of the net slag sales revenues or profits to the iron or steel company. Also, some slag may be returned to the furnaces for use as flux and as a supplemental source of iron.

Blast furnace slags are of three main types. The first, air-cooled blast furnace slag, is formed by allowing the molten slag to cool relatively slowly under ambient conditions; final cooling can be accelerated with a water spray. The cooled material is hard and dense, although it can have a vesicular texture with closed pores. After crushing and screening, air-cooled slag is used mainly as an aggregate for asphaltic paving, concrete, railway ballast, road bases and fill, and road metal. The second type of blast furnace slag is granulated slag. This is formed by quenching molten slag in water. The very rapid cooling causes solidification of the slag as sand-sized particles of glass. The disordered structure of this glass gives the material moderate hydraulic cementitious properties when very finely ground (finer than most grades of portland cement), but if it can access free lime, then the ground granulated blast furnace slag (GGBFS) develops strong hydraulic cementitious properties. There is a ready market for GGBFS as a partial substitute for portland cement in ready-mixed concrete or mixed with portland cement to make finished blended cement. In either application, the hydration of the portland cement releases the lime needed to activate the GGBFS. Concrete that contains a proportion of GGBFS generally develops strength more slowly than concretes containing only portland cement but can have similar or even superior long-term strength, releases less heat during hydration, has reduced permeability, and shows improved resistance to chemical attack. Granulated slag may lack cementitious properties as a result of unsuitable chemical composition, inadequate quenching, or because the slag is weathered (old slag piles). In such cases, granulated blast furnace slag can still be used as a fine grain aggregate for concrete. The third type of blast furnace slag, pelletized or expanded slag, is cooled through a water jet, which leads to rapid steam generation and the development of innumerable vesicles within the slag. The vesicular texture reduces the overall density of the slag, and allows for good mechanical binding with hydraulic cement paste. Pelletized slag in the United States is primarily used for lightweight concrete aggregate but, if very finely ground, also finds use as a supplementary cementitious material very similar to GGBFS.

Blast furnace slag (generally air-cooled) also can be made into mineral wool. Slag for this purpose is remelted and then poured through an air stream or jet of steam or other gas to produce a spray of molten droplets; alternatively, the droplets can be formed by passing the melt through a perforated or fast spinning disc. The droplets elongate into long fibers that are collected and layered. Mineral wool is mainly used for thermal insulation.

Steel furnace slag is cooled similarly to air-cooled blast furnace slag, has similar properties to it, and is used for many of the same purposes. To some degree, the properties of steel slags vary depending on the type of furnace that generated them. Basic oxygen furnaces principally refine crude iron into steel, whereas EAFs are mainly used to remelt steel scrap. Steel slags containing large amounts of dicalcium silicate are prone to expansion, and commonly are cured in piles for some months to allow for this and for leaching out of lime. If sold uncured, steel slags may not be appropriate for uses where a fixed product volume must be sustained.

Free-lime-bearing steel slags can have limited application as a soil conditioner. All slags can be used as raw materials for cement (clinker) manufacture (contributing part of the required aluminum, calcium, iron, and silicon oxides), but steel slags have proven to be especially suitable for this use.

Domestic Data Coverage

Data in this report are based on an annual U.S. Geological Survey (USGS) canvass of slag processors, and relate to sales of processed slag rather than to the amount of slag processed by the same firms or to the actual production of slag by iron and steel companies. Processed slag is sold from stockpiles, and although most of the material is a byproduct of current or recent iron and steel production, some is material mined from old slag piles (slag banks) and reflects iron and steel production from plants long since closed. In 2003, questionnaires were sent to 24 processing companies, covering 128 processing sites, and some form of data were received for all but 2 sites. The reported data account for about 99.9% of the gross tonnage for 2003 in table 1. In 2002, surveys went to 23 processing companies, covering 125 processing sites, and some form of response was received for all but 6 sites. The reported data account for about 93% of the 2002 tonnage in table 1. The data received in both years were primarily the gross tonnages, although in 2003 sufficient data concerning slag usage were received to allow for the addition of a table on slag use for the year (table 3). Data in USGS slag reports prior to 2002 contain a much higher component of estimates than in the 2002 and current reports. Comparison of pre-2002 data to data in the current report should thus be made with caution. Most significantly, the pre-2002 reports contained a data category (expanded slag) that was actually a combination of a significant (but incomplete) tonnage of granulated slag and a very small tonnage of pelletized slag that required proprietary protection. For the 2002 and 2003 reports, granulated slag data are directly revealed and are believed to be complete, and the pelletized slag data are omitted.

A list of slag processors, processing sites, and the iron and steel companies serviced is provided as table 4. Tracking the slag-processing industry is difficult because of frequent changes as to which company holds the processing contract for which steel mill, by the fact that integrated iron and steel mills can have more than one slag processor (each handling a different slag type), and by the fact that some processors handle only the cooling of the slag, which then gets processed further by another company.

Legislation and Government Programs

Demand for slag in the construction sector is influenced by State and Federal programs that affect construction spending levels. The main Federal funding program of this type continued to be the Transportation Equity Act for the 21st Century (TEA-21), but the effects of TEA-21 on slag consumption levels remained muted, and some projects partially funded under this act have been delayed owing to States having difficulty in cofunding the projects.

Most of the environmental issues (chiefly of emissions) associated with iron and steel manufacture tend to focus on the metal products and not on the slag. The widespread use of slags for, primarily, a variety of construction purposes has dramatically reduced the number and volume of unsightly slag piles. Slags are promoted as “sustainable” construction materials. Notably, through its use as a partial substitute for portland cement, GGBFS contributes to reducing the cement-production-related carbon dioxide emissions component of concrete and enhances the concrete’s durability.

Production

Despite the fact that production metallurgists and chemists at iron and steel plants commonly can quote the amount of slag in the blast furnace or steel furnace at any particular time, data are rare on the actual production of slag for an extended series of production cycles (heats). This generally is because not all of the slag is tapped during a heat, and the amount of slag tapped is not routinely measured. Accordingly, there are no data on U.S. production of ferrous slag and few, if any, data on foreign production, although both can be estimated.

The amount of slag produced largely is related to the overall chemistry of the raw material charges to the furnaces. For a blast furnace, the chief determinant is the overall grade of the iron ore. For an ore feed grading 60% to 66% iron, about 0.25 to 0.30 metric tons (t) of blast furnace slag will be produced per metric ton of crude iron. Lower grade ores yield more slag—sometimes as much as 1.0 to 1.2 t of slag per metric ton of crude iron. Steel slag output is also variable and depends on both the feed chemistry and the type of furnace used but is typically about 0.2 t of slag per metric ton of crude steel. However, up to 50% of the molten steel slag is entrained metal, most of which is generally recovered during slag processing and returned to the furnace. Thus the amount of marketable slag remaining after entrained steel removal is usually equivalent to about 10% to 15% of the crude steel output. Using these ratios and USGS data for U.S. and world iron and steel production, it was estimated that U.S. blast furnace slag production in 2003 was in the range of about 10 to 12 million metric tons (Mt), and world output was in the range of 160 to 200 Mt. Likewise, U.S. output of steel slag (after metal removal) in 2003 was estimated to be 9 to 14 Mt, and world output, 96 to 145 Mt.

Consumption

Although proportional to iron and steel output, correlation of slag production with slag sales (consumption) is only approximate. This is because slags may need to be cured for extended periods prior to sale, and it is common for slag processors to accumulate slag stockpiles either because of slow sales or to be able to bid on large construction projects. Most forms of processed slags have low unit values and thus generally cannot be transported very far economically.

Air-cooled and steel slags continue to dominate U.S. slag sales in terms of tonnage. Sales of air-cooled blast furnace slag totaled about 7.3 Mt in 2003, about the same level as in 2002 (table 1). Steel furnace slag sales rose by about 10% in 2003 to 8.8 Mt. These two slag types have a significant overlap in their uses (table 3). Although the sales price data for these slags contain a large component of estimates, it appears that the average selling price of air-cooled slag fell about 9% in 2003, whereas prices for steel slag appear to have changed very little (table 2). Major factors affecting the sales volumes and prices of these slags included local competition from natural aggregates, the overall level of construction activity (particularly that for roads), and the existence of some long-term supply contracts. Overall construction spending in 2003 was stagnant, but that for roads fell about 2%, compared with levels in 2002 [U.S. Census Bureau data cited by the Portland Cement Association (2004)].

As in 2002, sales of granulated slag accounted for about 80% of the value of blast furnace slag sales in 2003 and almost 72% of total slag sales. The tonnage of this material fell slightly in 2003 to 3.6 Mt (table 1). About 96% of total granulated slag sales in 2003 was of GGBFS, compared with about 90% in 2002. This relative decline in unground granulated slag sales was largely because of a decline in its use as a grinding aid in cement plant finish mills. Sales of GGBFS remained very strong and was for use as a supplementary cementitious material. The increase in the average price noted in table 2 reflects this larger GGBFS component of total granulated sales. The average price of cementitious unground granulated slag is only about one-half that of GGBFS (table 2), and if not cementitious, even lower. The USGS slag survey does not distinguish between granulated slag sold to cement companies and that sold directly to concrete companies, but the 2003 USGS cement survey indicated that the cement producers consumed only about 10% of this material. Sales of GGBFS under the name “slag cement” are promoted by the Slag Cement Association (SCA), whose members accounted for most of the U.S. production of this material. The SCA Web site reported sales of 3.1 Mt of GGBFS in 2003, which is in close agreement with the USGS data.

Imports of ferrous slags totaled about 1.1 Mt in 2003, virtually unchanged from those of 2002. The imports continued to be dominated by granulated blast furnace slag (unground). In 2003, imports of granulated slag totaled 0.75 Mt at an average unit price [cost, insurance, and freight (c.i.f.)] of about $35 per metric ton. These amounts were significantly lower than the imports in 2002 (0.86 Mt averaging about $38.50 per metric ton). Of the nine countries that supplied granulated slag in 2003, the largest sources were France (39%), Canada (24%), and Italy (18.5%).

Outlook

Despite the strong market and high prices realized for GGBFS, granulation cooling is currently installed at only five locations in the United States (two of these were installed in 2001); most of the remainder of the GGBFS was processed at about a dozen grinding plants that relied on imported unground feed. An additional grinding plant was under construction in Florida and was expected to be operational late in 2004. The attractiveness of installing granulators at additional blast furnace locations is mitigated by installation costs, the cost of constructing an associated grinding plant, and by the precarious health of the integrated iron and steel plants. Given the fact that the number of blast furnaces is in slow decline, continued growth in the domestic market for GGBFS will likely be met by adding additional import-based grinding capacity. A somewhat cheaper alternative to granulators is that of adding pelletization cooling, as was done in 2003 by Lafarge North America Inc. for Ispat-Inland Steel, Inc. in Indiana. Pelletized slag offers the option of being sold to the lightweight aggregate market or, after fine grinding, to the concrete industry. Although the market for slag as an aggregate will likely continue at about current levels for a number of years, sales during any particular year will continue to be threatened by shortfalls in construction spending. The availability of air-cooled slag is in slow decline owing to closures of some blast furnaces and depletion of some existing slag piles. Steel slag supply is more assured, owing to the relative abundance of EAFs.

Reference Cited

Portland Cement Association, 2004, Construction put in place: Monitor, v. 14, no. 5, May, p. 9.

General Sources of Information

U.S. Geological Survey Publication

Iron and Steel Slag. Ch. in Mineral Commodities Summaries, annual.

Other

National Slag Association.
Portland Cement Association.
Slag Cement Association.

TABLE 1
IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES

(Million metric tons and million dollars)

	2002					2003				
	Blast furnace slag[1]			Steel	Total iron	Blast furnace slag[1]			Steel	Total iron
	Air-cooled	Granulated	Total[2]	furnace slag	and steel slag[2]	Air-cooled	Granulated	Total[2]	furnace slag	and steel slag[2]
Quantity[3]	7.4	3.7	11.0	8.0 r	19.1 r	7.3	3.6	10.9	8.8	19.7
Value[e, 4]	55	210	265	30	294	49	212	261	35	296

[e]Estimated. [r]Revised.
[1]Excludes expanded (pelletized) slag to protect company proprietary data. The quantity is very small (less than 0.1 unit).
[2]Data may not add to totals shown because of independent rounding.
[3]Quantities are rounded to reflect inclusion of some estimated data and to reflect inherent accuracy limitations of reported data.
[4]Values are rounded because of the inclusion of a large estimated component.

TABLE 2
SELLING PRICES FOR IRON AND STEEL SLAG IN THE UNITED STATES[1]

(Dollars per metric ton)

	2002		2003	
Slag type	Range	Average	Range	Average
Blast furnace slag:				
Air-cooled	3.35–14.04	7.39	3.11-17.25	6.71
Granulated[2]	34.86–69.47	57.25	16.53-78.20	62.52
Steel slag	0.55–10.32	3.75	0.73-11.02	3.95

[1]Underlying data contain a very large component of estimates.
[2]Range shown is for material reported for use in a cementious additive in cement or concrete manufacture. Material at the low end of the range is sold in unground form.

TABLE 3

SALES OF FERROUS SLAGS IN THE UNITED STATES IN 2003, BY USE[1]

(Percentage of total sold)

Use	Blast furnace slag[2]	Steel slag[3]
Ready-mixed concrete	9.3	--
Concrete products	6.4	--
Asphaltic concrete	20.6	17.0
Road bases and surfaces	34.7	46.4
Fill	3.1	11.1
Clinker raw material	5.7	5.4
Miscellaneous[4]	4.0	2.5
Other or unspecified	16.2	17.6

-- Zero.

[1]Data contain a large component of estimates and are reliable to no more than two significant digits.

[2]Air-cooled slag only. Expanded or pelletized slag would have been sold mostly for lightweight aggregate or (when ground) as a cementitious additive for cement or concrete. Almost all granulated slag is sold as a cementitious additives for cement or concrete.

[3]Steel slag use is based on the 89% of total tonnage sold (table 1) for which usage data were provided.

[4]Reported as used for railroad ballast, roofing, mineral wool, or soil conditioner.

TABLE 4
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2003

			Slag and furnace types[1]					
			Blast furnace slag			Steel furnace slag		
Slag processing company	Plant location	Steel company serviced[2, 3]	AC	GG	Exp	BOF	OHF	EAF
Allega Slag Recovery[4]	Cuyahoga, OH	International Steel Group, Inc.	X					
AMSI	Holsopple, PA	North American Hoganas						X
Beaver Valley Slag	Aliquippa, PA	Old slag pile site	X				X	
Beaver Valley Slag (Thor Mill Services)	Roanoke, VA	Roanoke Electric Steel, Inc.						X
Blackheart Slag Co.	Muscatine (Montpelier), IA	IPSCO Steel, Inc.						X
Border Steel, Inc.[5]	El Paso, TX	Border Steel, Inc.						X
Buffalo Crushed Stone, Inc.	Woodlawn, NY	Old slag pile site	X					
Edward C. Levy Co.	Decatur (Trinity), AL	Nucor Steel Corp.						X
Do.	Butler, IN	Steel Dynamics, Inc.						X
Do.	Columbia City, IN	do.						X
Do.	Crawfordsville, IN	Nucor Steel Corp.						X
Do.	Detroit, MI	Rouge Steel Co.	X			X		
Do.	do.	Great Lakes Steel Co. (USX)	X			X		
Do.	Delta, OH	North Star--Bluescope Steel Inc.						X
Do.	Canton, OH	The Timken Co.						X
Do.	Huger, SC	Nucor Steel Corp.						X
Essroc Corp.	Middlebranch, OH	Misellaneous domestic and foreign		X				
Florida Rock Industries, Inc.	Tampa, FL[6]	Various foreign		X				
Gerdau AmeriSteel Corp.	Jacksonville, FL	Gerdau AmeriSteel Corp.						X
Glens Falls-Lehigh	Cementon, NY	Various foreign		X				
Heckett MultiServ Co.	Birmingham, AL	Structural Metals Corp.						X
Do.	Tuscaloosa, AL	Corus Tuscaloosa						X
Do.	Blytheville, AR	Nucor Steel Corp.						X
Do.	Blytheville (Armorel), AR	Nucor-Yamato Steel Co.						X
Do.	Pueblo, CO[7]	Rocky Mountain Steel Mills						X
Do.	Wilton (Muscatine), IA[8]	IPSCO Steel, Inc.						X
Do.	Wilton, IA	North Star Steel, Inc.						X
Do.	Chicago, IL	International Steel Group, Inc. (Riverdale)						X
Do.	East Chicago, IL	Ispat-Inland Steel, Inc.				X		
Do.	Indiana Harbor, IN	International Steel Group, Inc.						X
Do.	Coalton, KY	NS Group, Inc. (Newport Steel)						X
Do.	Ghent, KY	Gallatin Steel Co.						X
Do.	do.	North American Stainless LP						X
Do.	Sparrows Point, MD	International Steel Group, Inc.	X			X		
Do.	Ahoskie (Cofield), NC	Nucor Steel Corp.						X
Do.	Canton, OH	Republic Engineered Products LLC						X
Do.	Mansfield, OH	AK Steel Corp.				X		
Do.	Warren, OH	WCI Steel, Inc.				X		
Do.	Braddock, PA	U.S. Steel/Republic Technologies				X		
Do.	Butler, PA	AK Steel Corp.						X
Do.	Coatsville, PA	International Steel Group, Inc.						X
Do.	Koppel, PA	Koppel Steel Co. (NS Group, Inc.)						X
Do.	Steelton, PA	International Steel Group, Inc.						X
Do.	Midlothian, TX	TXI Chaparral Steel Co.						X
Do.	Geneva (Provo), UT[9]	Geneva Steel Holdings Corp.	X			X		
Do.	Seattle, WA	Nucor Steel Corp.						X
Holcim (US) Inc.	Gary, IN	U.S. Steel LLC		X				
Do.	Weirton, WV	Weirton Steel Corp.		X				
Do.	Birmingham (Fairfield), AL	U.S. Steel LLC		X				
International Mill Services	Axis, AL	IPSCO Steel, Inc.						X
Do.	Fort Smith, AR	Macsteel Co.						X
Do.	Kingman, AZ	North Star Steel, Inc.						X
Do.	Pueblo, CO[7]	Rocky Mountain Steel Mills						X
Do.	Claymont, DE	Citisteel USA, Inc.						X
Do.	Cartersville, GA	Gerdau AmeriSteel Corp.						X
Do.	Wilton (Muscatine), IA[8]	North Star Steel, Inc.						X
Do.	Kankakee, IL	Nucor Steel Corp.						X
Do.	Peoria, IL	Keystone Steel & Wire Co.						X
Do.	Laplace, LA	Bayou Steel Co.						X
Do.	Jackson, MI	Macsteel Co.						X
Do.	Monroe, MI	Macsteel Co. (Quanex)						X

See footnotes at end of table.

TABLE 4--Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2003

			Slag and furnace types[1]					
			Blast furnace slag			Steel furnace slag		
Slag processing company	Plant location	Steel company serviced[2, 3]	AC	GG	Exp	BOF	OHF	EAF
International Mill Services--Continued	St. Paul, MN	North Star Steel, Inc.						X
Do.	Jackson, MS	Birmingham Steel Corp.						X
Do.	Charlotte, NC	Gerdau AmeriSteel Corp.						X
Do.	Perth Amboy, NJ	do.						X
Do.	Sayreville, NJ	do.						X
Do.	Auburn, NY	Nucor Steel Corp.						X
Do.	Marion, OH	Marion Steel Co.						X
Do.	McMinnville, OR	Cascade Steel Rolling Mills, Inc.						X
Do.	Portland, OR	Oregon Steel Mill, Inc.						X
Do.	Bethlehem, PA	Old slag pile site	X			X		
Do.	Bridgeville, PA	Universal Stainless & Alloy Products Inc.						X
Do.	Johnstown, PA	Old slag pile site						X
Do.	Midland, PA	J&L Specialty Products, Inc.						X
Do.	Monroeville, PA	Old slag pile site		X			X	
Do.	New Castle, PA	Ellwood Quality Steels, Inc.						X
Do.	Park Hill, PA	Old slag pile site				X		
Do.	Pricedale, PA	do.				X		
Do.	Reading, PA	Carpenter Technology Corp.						X
Do.	Darlington, SC	Nucor Steel Corp.						X
Do.	Georgetown, SC	Georgetown Steel Corp.						X
Do.	Jackson, TN	Gerdau AmeriSteel Corp.						X
Do.	Beaumont, TX	North Star Steel, Inc.						X
Do.	El Paso, TX[5]	Border Steel, Inc.						X
Do.	Jewett, TX	Nucor Steel Corp.						X
Do.	Longview, TX	LeTourneau Steel Group						X
Do.	Plymouth, UT	Nucor Steel Corp.						X
Do.	Saukville, WI	Charter Steel						X
Do.	Weirton, WV	Weirton Steel Corp.				X		
Lafarge North America Inc.	Tampa, FL[6]	Various foreign		X				
Do.	Sparrows Point, MD	International Steel Group, Inc.		X				
Do.	Joppa, IL	Ispat-Inland Steel, Inc.		X				
Do.	South Chicago, IL	do.		X	X			
Do.	Lordstown, OH	Old slag pile site		X				
Do.	McDonald, OH	Youngstown Sheet and Tube Co.	X					
Do.	Warren, OH	WCI Steel, Inc.	X					
Do.	Salt Springs (Youngstown), OH	Youngstown Sheet and Tube Co.	X					
Do.	West Mifflin, PA	U.S. Steel LLC (ET Works)	X					
Do.	West Mifflin (Brown Reserve), PA	Old slag pile site	X					
Do.	Whitehall, PA	Various foreign		X				
Do.	Seattle, WA	do.		X				
Do.	Weirton, WV	Weirton Steel Corp.	X					
Lehigh Cement	Evansville, PA	Various foreign		X				
Levy Co., Inc., The	Burns Harbor, IN	International Steel Group, Inc.	X			X		
Do.	East Chicago, IN	do.	X					
Do.	Gary, IN	U.S. Steel LLC (ET Works)	X	X				
Lone Star Inc.	New Orleans, LA	Various foreign		X				
Olympic Mill Services Inc.	Birmingham, AL	Birmingham Steel Corp.						X
Do.	Newport, AR	Arkansas Steel Assoc.						X
Do.	Rancho Cucamonga, CA	TAMCO Steel						X
Do.	Portage, IN	Beta Steel Corp.						X
Do.	Norfolk, NE	Nucor Steel Corp.						X
Do.	Middletown, OH	AK Steel Corp.	X			X		
Do.	Mingo Junction, OH	Wheeling Pittsburgh Steel Corp.	X			X		
Do.	Youngstown, OH	V&M Star (North Star) Inc.						X
Do.	Sand Springs, OK	Sheffield Steel Corp.						X
Do.	Cayce, SC	CMC Steel Group						X
Do.	Seguin, TX	do.						X
Do.	Knoxville, TN	Gerdau AmeriSteel Corp.						X
Do.	Petersburg, VA	TXI Chaparral Steel Co.						X
Rinker Materials Corp.	Miami, FL	Various foreign		X				

See footnotes at end of table.

TABLE 4--Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2003

			Slag and furnace types[1]					
			Blast furnace slag			Steel furnace slag		
Slag processing company	Plant location	Steel company serviced[2, 3]	AC	GG	Exp	BOF	OHF	EAF
St. Marys Cement Co.	Detroit, MI	Various foreign		X				
Stein, Inc.	Sterling, IL	Sterling Steel, Inc.						X
Do.	Ashland, KY[10]	AK Steel Corp.	X			X		
Do.	Cleveland, OH[4, 10]	International Steel Group, Inc.	X			X		
Do.	Loraine, OH	Republic Engineered Products LLC	X			X		
St. Lawrence Cement Co.	Camden, NJ	Various foreign		X				
Tarmac America Inc.	Medley, FL	do.		X				
Vulcan Materials Co.	Fairfield, AL	U.S. Steel LLC	X			X		

[1]Blast furnace slag type abbreviations: AC--air-cooled; GG--granulated; Exp--expanded. Steel furnace slag types: BOF--basic oxygen furnace; OHF--open hearth furnace; EAF--electric arc furnace.

[2]"Various foreign" refers to the fact that the facility imports unground granulated blast furnace slag and grinds it onsite to make ground granulated blast furnace slag, commonly now referred to as "slag cement."

[3]Currently operating iron and/or steel company. Company is not shown for old slag pile sites.

[4]Processing contract for air-cooled slag transferred to Stein, Inc. late in the year; Stein already had the steel slag contract.

[5]Processing function transferred to Border Steel, Inc. at beginning of year.

[6]Grinding plant was sold by Lafarge Corp. to Florida Rock Industries in mid-2003.

[7]Processing contract transferred to Heckett MultiServe in April.

[8]Processing contract transferred to International Mill Services in July.

[9]The Geneva Steel plant shut down in 2002; slag processing in 2003 was of small residual piles.

[10]For the air-cooled slag, Stein was responsible for the cooling, but the processing and marketing was handled by Lafarge (Cleveland) and Mountain Enterprises, Inc. (Ashland).